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REPRESENTATIVE ELECTROMAGNETIC FIELD INTENSITIES NEAR
THE CLAM LAKE ELF (EXTREMELY LOW FREQUENCY) FACILITY
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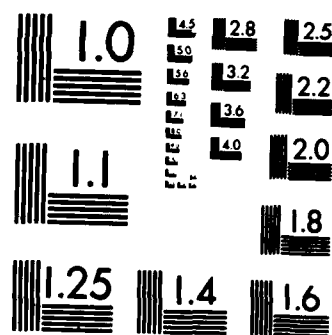
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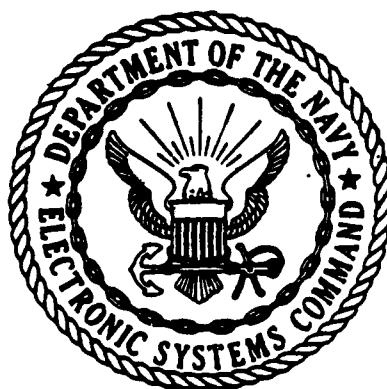


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REPRESENTATIVE ELECTROMAGNETIC FIELD INTENSITIES NEAR THE CLAM LAKE ELF FACILITY

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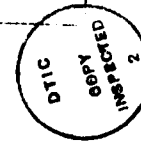
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REPRESENTATIVE ELECTROMAGNETIC FIELD INTENSITIES NEAR THE CLAM LAKE ELF FACILITY

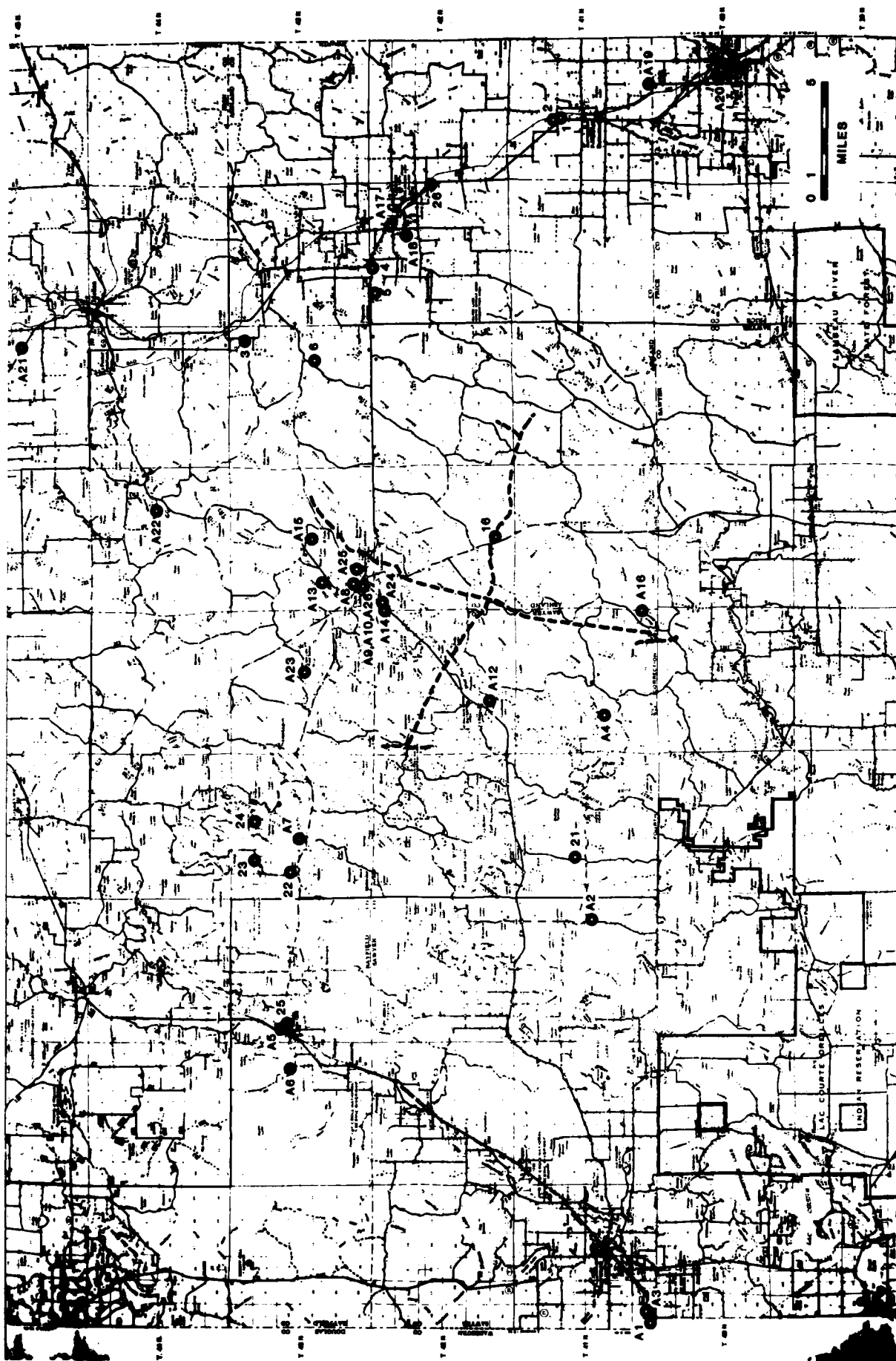
PURPOSE

Electromagnetic field intensities produced by Extremely Low Frequency (ELF) communications antennas and commercial power transmission and distribution systems have been measured at numerous places near the Navy's ELF Communications Facility at Clam Lake, Wisconsin. The purpose of the measurements was to obtain a representative sampling of the field intensities which exist where people live and work, and at places residents and visitors might use for recreation and other purposes.

Electromagnetic fields are produced by currents and voltages on ELF antennas and commercial power lines. The currents produce magnetic flux densities in air and earth. The magnetic flux densities in earth also produce electric fields in earth. The voltages on ELF antennas and power lines produce electric fields in air. These fields principally exist at the operating frequencies of the sources, which are 76 Hz for the ELF antennas at Clam Lake, and 60 Hz for commercial power lines. The fields at these two distinct frequencies do not combine in either air or earth to produce other fields at other frequencies. They simply exist simultaneously in time and space when ELF antennas are operated and customers use electric service. The data in this report describe these magnetic fields and electric fields in air and earth at their source frequencies and their intensities at representative places in the Clam Lake area.

SELECTION OF MEASUREMENT LOCATIONS

The Navy's ELF Communications Facility is located within the Chequamegon National Forest in northwestern Wisconsin, see Figure 1. The transmitter station, the antennas and the ground terminals are located entirely on public land. The small, unincorporated village of Clam Lake is the closest population center, and is slightly more than a mile west of the north leg of the ELF antenna system. The town of Cable, with a population of several hundred, is further west, and is about 15 miles from the nearest ELF antenna. Hayward,



**FIGURE 1 ELF COMMUNICATIONS FACILITY
AND ELECTROMAGNETIC FIELDS MEASUREMENTS LOCATIONS**

also west of the Navy facility (about 25 miles), has a permanent population of several thousand, with seasonal increases as high as tens of thousands.

The small towns of Glidden and Butternut are about the size of Cable and lie about 10 miles east of the ELF Facility. The City of Park Falls, with a population of several thousand, is about 20 miles to the southwest.

There are seasonal and year-round dwellings along highways between towns, and clusters of homes around lakes. Most are five or more miles from the nearest ELF antenna. All are served by electric utilities, but there are no high voltage transmission lines in the immediate region.

Electromagnetic field intensities were measured at six private residences in Clam Lake, Cable, Glidden and Butternut. Four utility offices represented workplaces. A resort apartment represented a place where visitors reside temporarily. Two business places in Clam Lake represented locations where residents work and the public frequently visits. Two government offices also represented workplaces where the public sometimes visits. A lumber warehouse in Hayward best represented an industrial workplace where the public also sometimes frequents. A field site used as a summer student encampment represented an educational facility.

Electromagnetic field intensities also were measured where people neither live nor work. Those locations represented places used for recreation or other occasional uses. They included campgrounds in the Chequamegon National Forest, a wayside along a highway, a pipeline right-of-way popular with hunters, and forested places and meadows used for recreation.

MEASUREMENT RESULTS

Results of measured magnetic field intensities and electric field intensities at 76 Hz and 60 Hz are illustrated graphically in Figures 2 through 9. The 76 Hz field intensities are produced by the ELF Communications antennas, and also appear as induced 76 Hz voltages and currents on power lines. The 60 Hz field intensities are produced by commercial power distribution systems and electrical equipment and appliances used by consumers. Methods of measurement and tabular data are included in Appendix A.

Figure 2
MEASURED MAGNETIC FIELD INTENSITIES
AT INHABITED PLACES
NEAR THE CLAM LAKE ELF FACILITY
(OUTDOOR MEASUREMENTS)

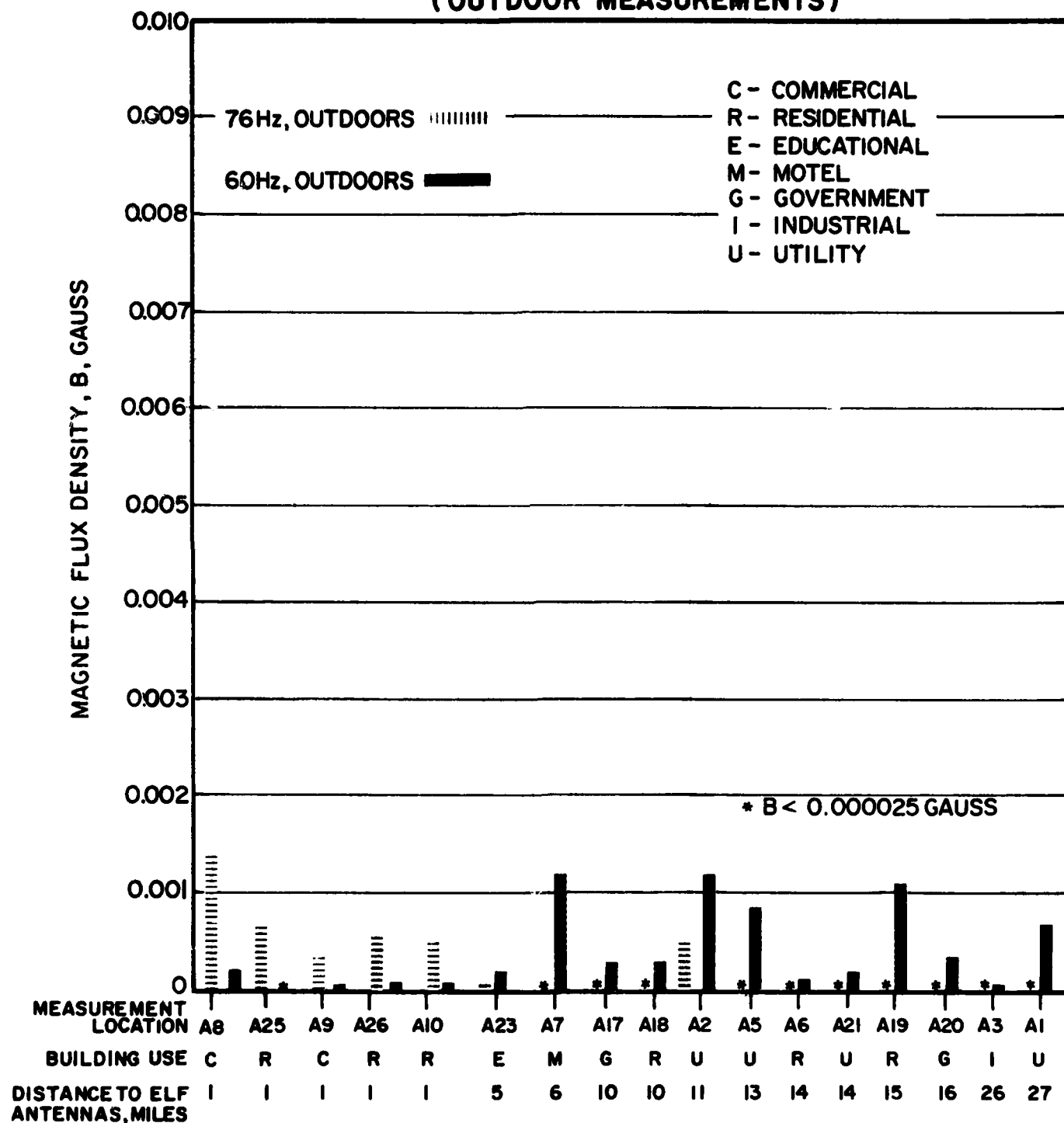


Figure 3
MEASURED MAGNETIC FIELD INTENSITIES
AT INHABITED PLACES
NEAR THE CLAM LAKE ELF FACILITY
(INDOOR MEASUREMENTS)

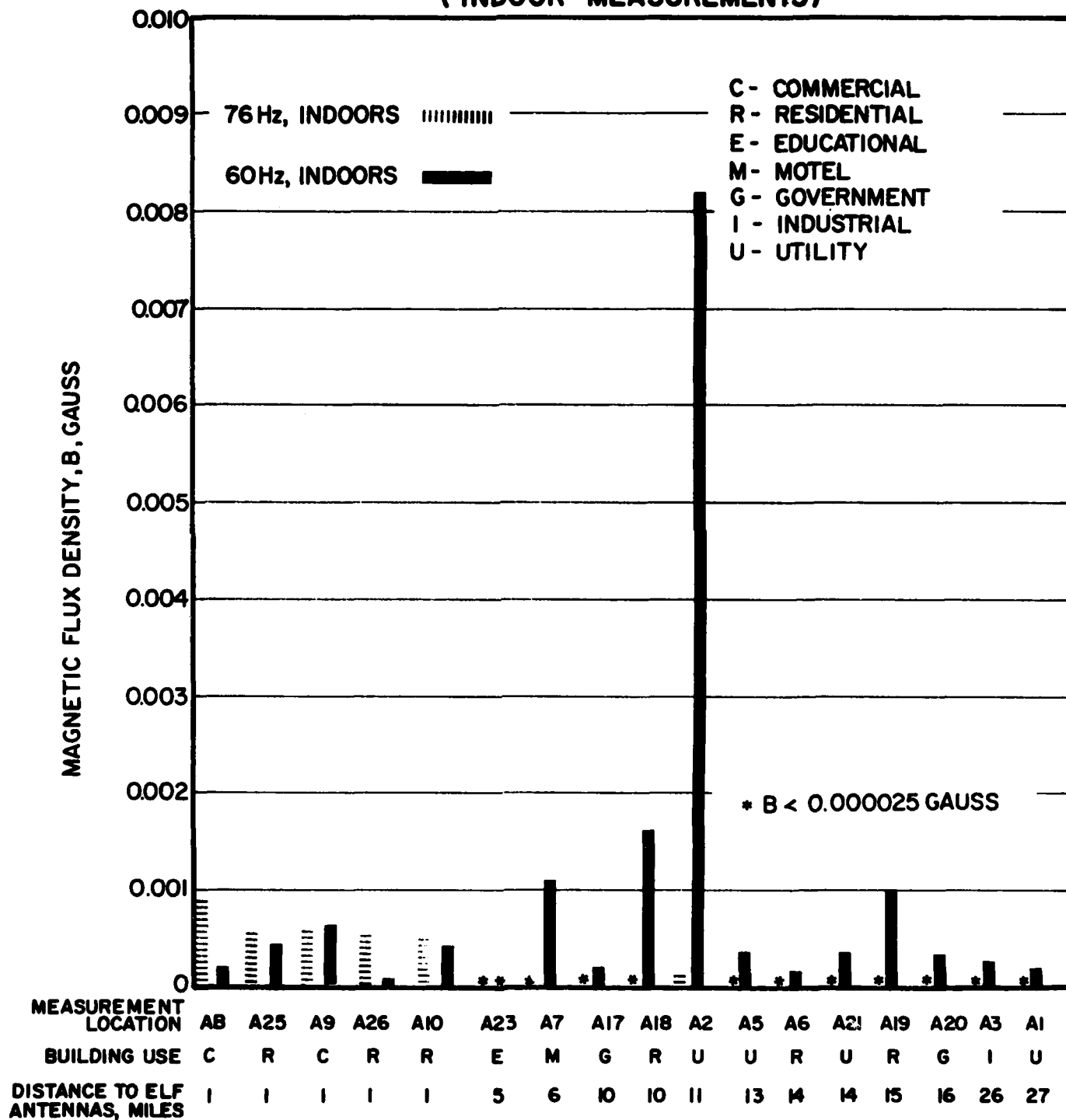


Figure 4

MEASURED MAGNETIC FIELD INTENSITIES
AT CASUALLY-OCCUPIED PLACES
NEAR THE CLAM LAKE ELF FACILITY

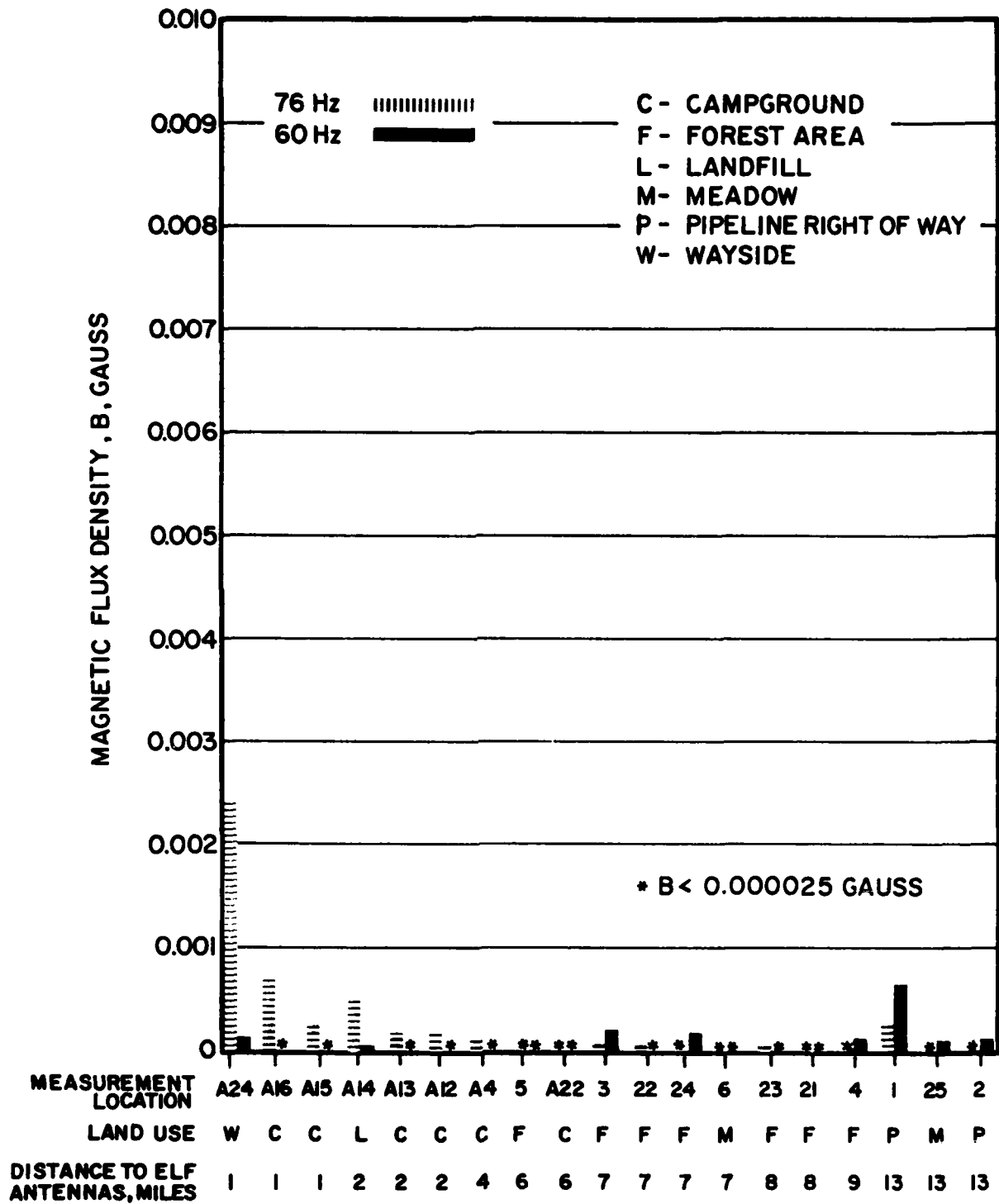


Figure 5

MEASURED ELECTRIC FIELD INTENSITIES IN SOIL AT INHABITED PLACES NEAR THE CLAM LAKE ELF FACILITY

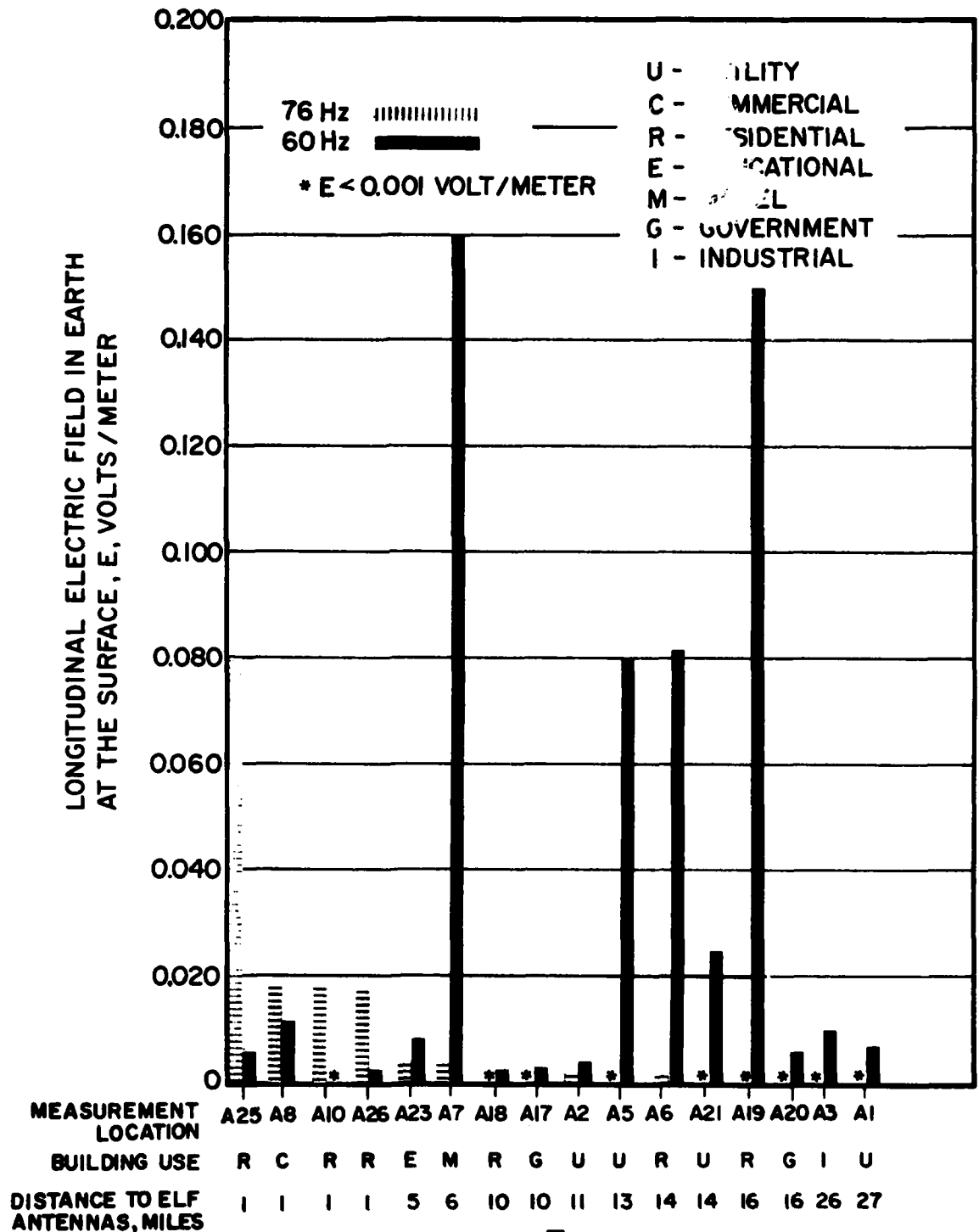


Figure 6

MEASURED ELECTRIC FIELD INTENSITIES
IN SOIL AT CASUALLY-OCCUPIED PLACES
NEAR THE CLAM LAKE ELF FACILITY

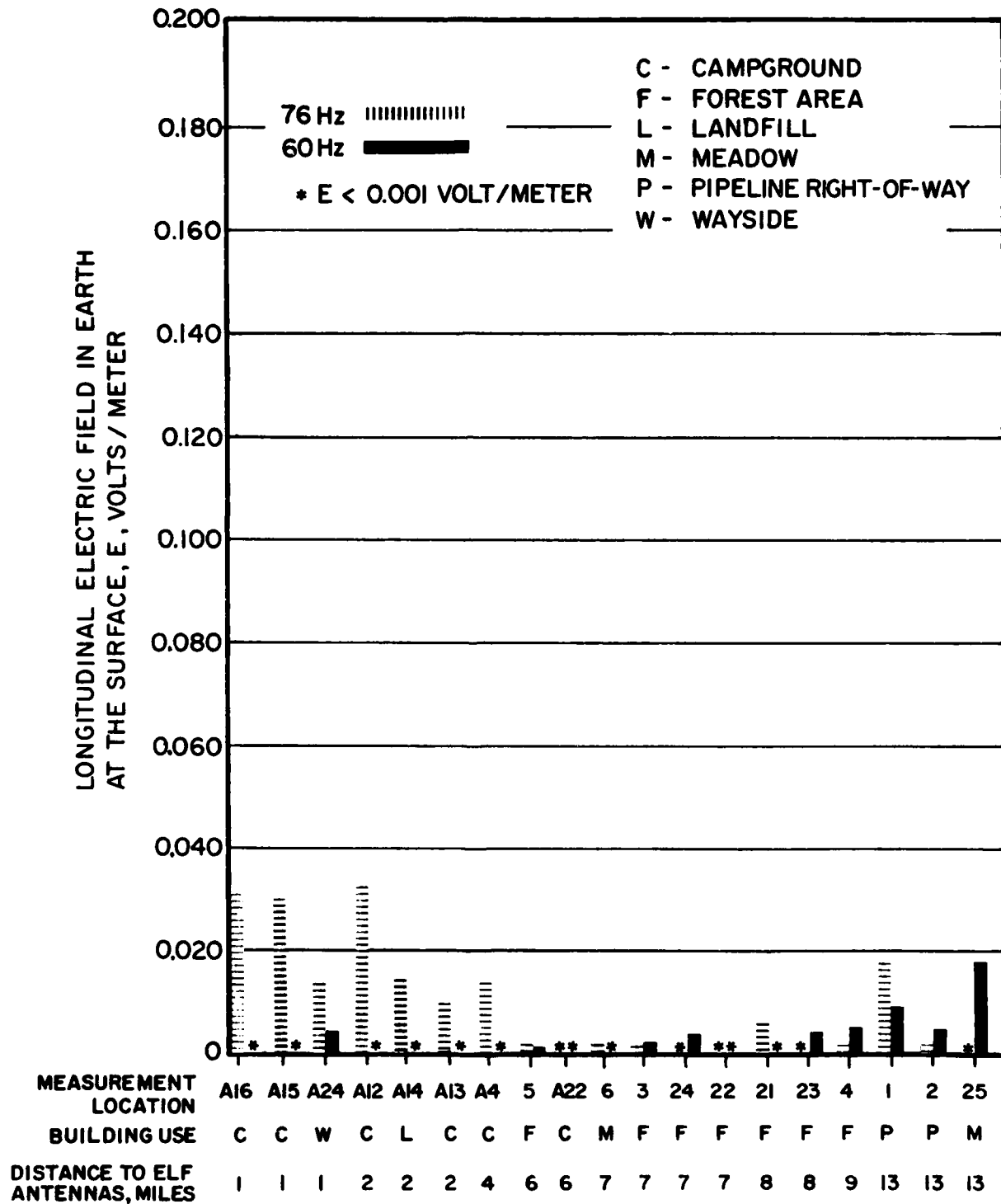


Figure 7

MEASURED ELECTRIC FIELD INTENSITIES
IN AIR AT INHABITED PLACES
NEAR THE CLAM LAKE ELF FACILITY
(OUTDOOR MEASUREMENTS)

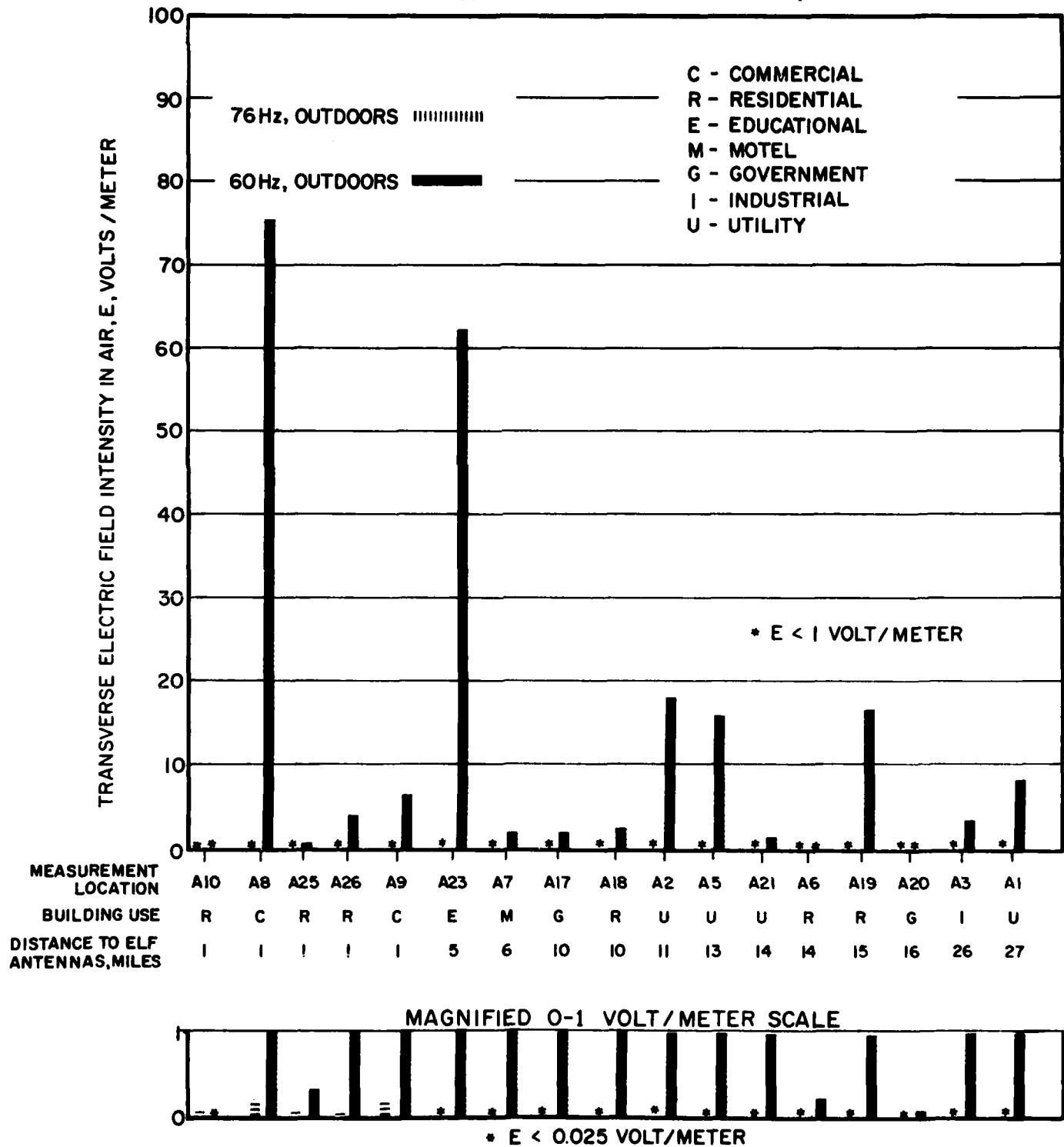


Figure 8

MEASURED ELECTRIC FIELD INTENSITIES
IN AIR AT INHABITED PLACES
NEAR THE CLAM LAKE ELF FACILITY
(INDOOR MEASUREMENTS)

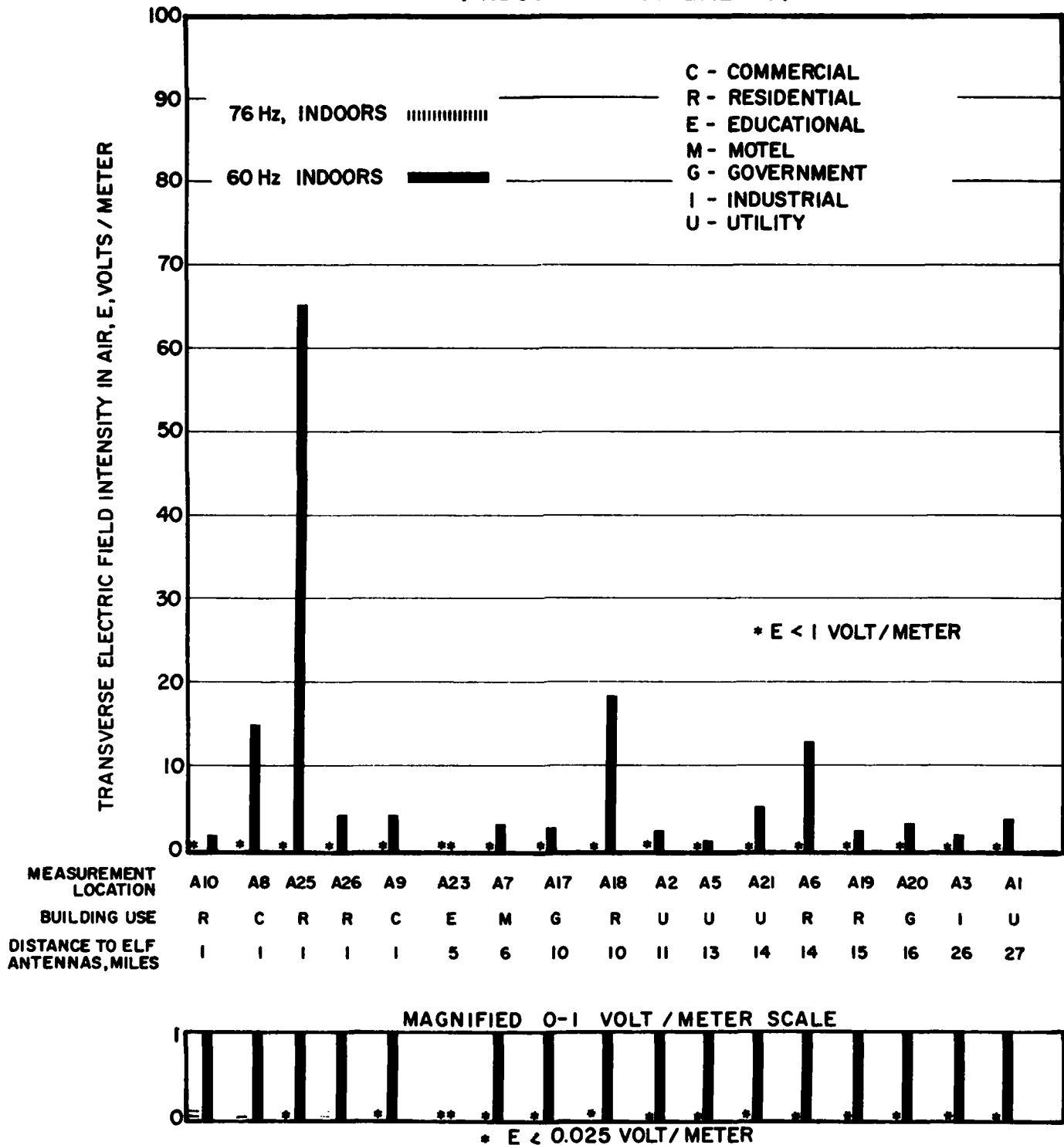
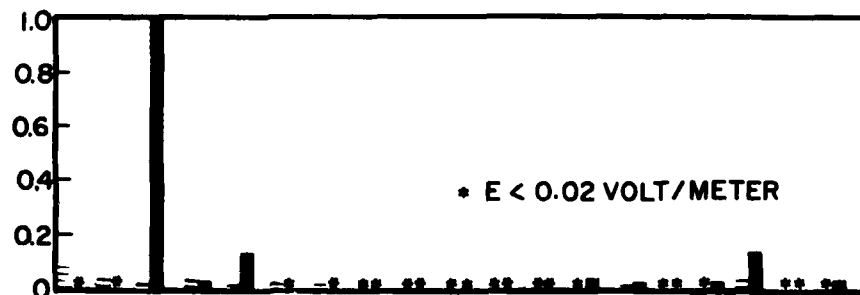
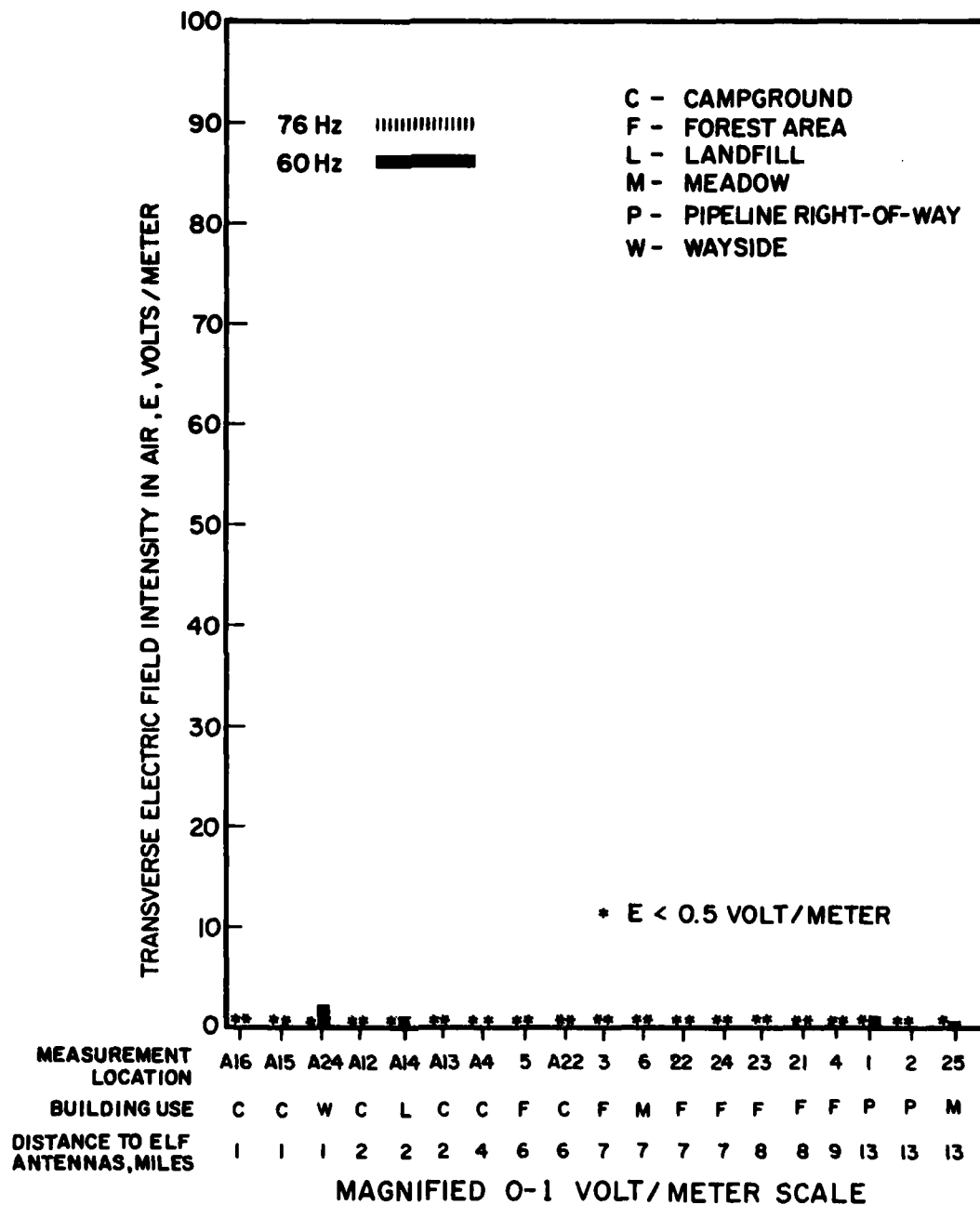


Figure 9
MEASURED ELECTRIC FIELD INTENSITIES
IN AIR AT CASUALLY-OCCUPIED PLACES
NEAR THE CLAM LAKE ELF FACILITY



DISCUSSION OF RESULTS

Magnetic Fields

Magnetic field intensities produced by commercial power line currents are weak where people live and work in the Clam Lake region. Figures 2 and 3 show that the line currents generate low magnetic field intensities in air and earth. Higher magnetic field intensities can be measured close to many appliances, and measurements made indoors and graphically presented in Figure 3 represent a composite of magnetic field contributions from numerous operating appliances. Measured magnetic flux densities near some types of electrical appliances are listed in Appendix B. The 60 Hz magnetic fields measured outdoors are produced by the power line currents drawn by consumers. In most cases measured magnetic field intensities were higher indoors than outdoors. The 60 Hz magnetic field intensities are somewhat lower at Clam Lake than elsewhere because new multiphase power lines were built there to prevent interference nuisances to utility customers. A magnetic field cancelling effect occurs between multiple phase wires of a power line, but is absent on older single phase power lines found further from the ELF facility.

The 76 Hz magnetic fields diminish rapidly as a function of distance from the ELF communications antennas. As Figures 2 and 3 show, the 76 Hz fields were lower than 60 Hz fields except where measured in Clam Lake, the population center closest to the ELF antennas (about one mile away). The 76 Hz magnetic field intensities indoors were practically the same as those measured outdoors at each location.

Measured magnetic field intensities were very low at both 60 Hz and 76 Hz in areas used for recreation and other purposes on an occasional basis, as is shown in Figure 4.

Electric Fields in Soil

As noted earlier in this report, magnetic flux densities produced in air and earth by power lines and ELF antenna currents result in electric fields in earth. Since the magnetic field intensities illustrated in Figures 2 and 4 are low, the electric field intensities induced in earth also are low, as

shown in Figures 5 and 6. The data show the same trends as discussed above for magnetic field intensities (higher fields near buildings than in open areas, higher 60 Hz intensities a mile and more distant from ELF antennas, lower 60 Hz intensities where power lines have been reconstructed, etc.), and for the same reasons. Appendix B includes information on electric fields measured in earth in the vicinity of various types of circuits which may be of interest to readers.

Electric Fields in Air

Electric fields in air are determined by circuit voltages. An electric field under an ordinary 7200-volt power distribution line is less than the field under a 345,000-volt transmission line, for example (see Appendix B). The 60 Hz electric field intensities measured near buildings in the Clam Lake area (Figure 7) are produced by power lines serving customers. The fields measured indoors are generally lower than those outdoors, and are produced by operating electrical appliances (see Appendix B). The 60 Hz fields measured in air are low because low voltage power lines are predominantly used in the rural Clam Lake Region.

Figure 7 shows that the 76 Hz electric field intensities measured in and near buildings were much lower than 60 Hz fields. Both 60 Hz and 76 Hz electric field intensities in air were very low in open recreational areas due to the distances from recreational points to power lines and ELF antennas, see Figure 8.

SUMMARY

Electromagnetic fields (magnetic field intensities and electric field intensities in air and earth) constituting the Extremely Low Frequency (ELF) electromagnetic environment in the Clam Lake, Wisconsin region are produced by two sources: commercial power lines and the U.S. Navy's ELF Communications Facility. The power lines produce very low intensity 60 Hz magnetic and electric fields from currents drawn by consumers and the voltages of the lines respectively. The magnetic and electric field intensities produced at 76 Hz by the Navy's facility also are very low for several reasons. People reside a mile and more from the ELF antennas, and currents and voltages

induced at 76 Hz on power lines serving consumers are maintained at low levels to avoid electrical interference. At other open, recreational places power lines are generally absent, thus there are no nearby induced 76 Hz currents and voltages, and the ELF antennas are sufficiently distant that fields produced by antenna currents and voltages are greatly diminished.

A P P E N D I X A

MAGNETIC FIELD INTENSITY

Magnetic field intensities were sensed with a single-axis, multi-turn probe with a ferrite core. The probe is calibrated in a known magnetic field in the laboratory so that the output voltage is proportional to field intensity. Three types of tuned voltmeters were used with the probe to obtain measured data. The voltmeter type depended upon availability and appropriateness for the desired measurement, and included a tuned voltmeter specially developed for ELF Communications Program research and experimentation, a Hewlett-Packard Model 302A wave analyzer, and a Hewlett-Packard Model 3581A signal wave analyzer.

Magnetic field intensity was sensed in three orthogonal directions at each measurement location: two perpendicular directions in the horizontal plane, and the vertical direction. The root-sum-square (rss) value of the three measurements was then computed to obtain the resultant magnetic field intensity at each frequency at each measurement site. A one meter probe height was maintained at each location. The 76 Hz data represented ELF antenna operations at 300 amperes (simultaneous in North-South and East-West antennas).

ELECTRIC FIELD INTENSITY IN SOIL

Electric field intensities in soil were measured with an electric field probe developed for ELF Communications Program research and experimentation. The probe consists of two metal stakes mounted on a nonconductive triangular frame with appropriate electric cables. Force is placed on the frame so that the metal stakes penetrate soil to a known depth at two points one meter apart. The potential difference between the probes is measured with a tuned voltmeter to obtain measures of field intensity.

Electric field intensities in soil were measured in two orthogonal directions in the horizontal plane at each measurement location and at each frequency. The rss value of the two measurements at each location was then computed to obtain the resultant electric field intensity at each frequency at each measurement site. Tuned voltmeters identified above were used.

Resulting data at 76 Hz represented simultaneous 300-ampere ELF antenna operations.

ELECTRIC FIELD INTENSITY IN AIR

Electric field intensities in air were measured with an ELF electric field probe developed for ELF Communications Program research and experimentation.* The probe consists of two insulated hemispheres which form a split, 6 centimeter diameter sphere when assembled. The electric field on the sphere's axis is sensed, and a modulated light replica of the field is transmitted to a measurement receiver by an optical fiber cable. The receiver reconverts the light signal to an electrical signal, which is then measured by a tuned voltmeter (see identification above) as field intensity at the sphere's axis.

Electric field intensities were measured at each location and at each frequency in the same planes and directions noted above for magnetic field intensity measurements. The rss value of the field was then computed at each location and frequency. The probe height was maintained at one meter for all measurements. Resulting data at 76 Hz represented simultaneous 300 ampere ELF antenna operations.

MEASURED DATA

The rss value of measured magnetic and electric field intensities at 60 Hz and 76 Hz at all measurement locations used in this study are listed in Tables A-1 through A-6.

* V. Formanek; An Improved ELF Electric Field Probe; IIT Research Institute, Technical Memorandum E 6249-2; March 1974.

TABLE A-1

MEASURED MAGNETIC FIELD INTENSITIES AT INHABITED PLACES
NEAR THE CLAM LAKE ELF FACILITY

MEASURE- MENT LOCATION	BUILD- ING USE	DISTANCE TO ELF ANTENNA (Miles)	76 Hz		60 Hz	
			INDOORS (GAUSS)	OUTDOORS	INDOORS (GAUSS)	OUTDOORS
A8	C	1	0.000870	0.001400	0.000170	0.000210
A25	R	1	0.000520	0.000630	0.000410	0.000008
A9	C	1	0.000560	0.000340	0.000620	0.000038
A26	R	1	0.000510	0.000540	0.000071	0.000026
A10	R	1	0.000490	0.000510	0.000400	0.000056
A23	E	5	-	0.000047	-	0.000120
A7	M	6	0.000010	0.000011	0.001100	0.001200
A17	G	10	0.000008	0.000035	0.000210	0.000270
A18	R	10	0.000013	0.000010	0.001600	0.000270
A2	U	11	0.000110	0.000480	0.008200	0.001200
A5	U	13	0.000005	0.000008	0.000340	0.000870
A6	R	14	0.000005	0.000002	0.000120	0.000100
A21	U	14	0.000002	0.000002	0.000360	0.000170
A19	R	15	0.000002	0.000002	0.001000	0.001100
A20	G	16	0.000003	0.000004	0.000300	0.000330
A3	I	26	0.000001	0.000001	0.000260	0.000062
A1	U	27	0.000001	0.000003	0.000170	0.000650

C - COMMERCIAL
R - RESIDENTIAL
E - EDUCATIONAL
M - MOTEL
G - GOVERNMENT
I - INDUSTRIAL
U - UTILITY

TABLE A-2

MEASURED MAGNETIC FIELD INTENSITIES AT CASUALLY-OCCUPIED PLACES
NEAR THE CLAM LAKE ELF FACILITY

MEASUREMENT LOCATION	LAND USE	DISTANCE TO ELF ANTENNAS (Miles)	76 Hz (GAUSS)	60 Hz (GAUSS)
A24	W	1	0.002400	0.000083
A16	C	1	0.000650	< 0.000001
A15	C	1	0.000250	0.000003
A14	L	2	0.000450	0.000028
A13	C	2	0.000180	0.000011
A12	C	2	0.000180	< 0.000001
A4	C	4	0.000088	0.000004
5	F	6	0.000022	0.000008
A22	C	6	0.000011	< 0.000001
3	F	7	0.000033	0.000200
22	F	7	0.000032	0.000013
24	F	7	0.000023	0.000160
6	M	7	0.000011	< 0.000001
23	F	8	0.000030	0.000024
21	F	8	0.000009	0.000004
4	F	9	0.000016	0.000110
1	P	13	0.000230	0.000660
25	M	13	0.000020	0.000093
2	P	13	0.000020	0.000087

C - Campground
F - Forest Area
L - Landfill
M - Meadow
P - Pipeline Right-of-Way
W - Wayside

TABLE A-3

MEASURED ELECTRIC FIELD INTENSITIES IN SOIL AT INHABITED PLACES
NEAR THE CLAM LAKE ELF FACILITY

MEASUREMENT LOCATION	BUILDING USE	DISTANCE TO ELF ANTENNAS (Miles)	76 Hz (VOLTS/METER)	60 Hz (VOLTS/METER)
A25	R	1	0.08000	0.00490
A8	C	1	0.01800	0.01100
A10	R	1	0.01800	0.00082
A26	R	1	0.01700	0.00380
A23	E	5	0.00370	0.07900
A7	M	6	0.00310	0.16000
A18	R	10	0.00067	0.02100
A17	G	10	0.00029	0.00300
A2	U	11	0.00110	0.00350
A5	U	13	0.00033	0.08000
A6	R	14	0.00130	0.08200
A21	U	14	0.00009	0.02500
A19	R	15	0.00023	0.15000
A20	G	16	< 0.00005	0.00550
A3	I	26	< 0.00005	0.00960
A1	U	27	< 0.00005	0.00640

C - COMMERCIAL
R - RESIDENTIAL
E - EDUCATIONAL
M - MOTEL
G - GOVERNMENT
I - INDUSTRIAL
U - UTILITY

TABLE A-4

MEASURED ELECTRIC FIELD INTENSITIES IN SOIL AT CASUALLY-OCCUPIED PLACES
NEAR THE CLAM LAKE ELF FACILITY

MEASUREMENT LOCATION	LAND USE	DISTANCE TO ELF ANTENNAS (Miles)	76 Hz (VOLTS/METER)	60 Hz (VOLTS/METER)
A16	C	1	0.03000	< 0.00005
A15	C	1	0.02900	0.00018
A24	W	1	0.01300	0.00390
A12	C	2	0.03200	< 0.00005
A14	L	2	0.01400	0.00043
A13	C	2	0.00890	0.00024
A4	C	4	0.01300	0.00020
5	F	6	0.00160	0.00110
A22	C	6	0.00031	0.00026
6	M	7	0.00140	0.00010
3	F	7	0.00120	0.00160
24	F	7	0.00030	0.00360
22	F	7	0.00030	0.00020
21	F	8	0.00570	0.00020
23	F	8	0.00070	0.00170
4	F	9	0.00150	0.00550
1	P	13	0.01700	0.00840
2	P	13	0.00070	0.00460
25	M	13	< 0.00005	0.01800

C - Campground
F - Forest Area
L - Landfill
M - Meadow
P - Pipeline Right-of-Way
W - Wayside

TABLE A-5

MEASURED ELECTRIC FIELD INTENSITIES IN AIR AT INHABITED PLACES
NEAR THE CLAM LAKE ELF FACILITY

MEASURE- MENT LOCATION	BUILD- ING USE	DISTANCE TO ELF ANTENNAS (Miles)	76 Hz (VOLTS/METER)		60 Hz (VOLTS/METER)	
			INDOORS	OUTDOORS	INDOORS	OUTDOORS
A10	R	1	0.120	0.031	1.70	0.021
A8	C	1	0.043	0.160	15.2	75.0
A25	R	1	0.024	0.065	65.2	0.310
A26	R	1	0.091	0.038	4.30	3.80
A9	C	1	0.007	0.160	4.20	7.30
A23	E	5	-	0.013	-	62.6
A7	M	6	0.010	0.010	3.30	1.80
A17	G	10	0.008	< 0.003	2.80	1.80
A18	R	10	< 0.003	< 0.003	18.7	2.10
A2	U	11	0.010	0.021	2.60	18.1
A5	U	13	< 0.003	< 0.003	1.50	16.1
A21	U	14	0.009	< 0.003	5.40	1.30
A6	R	14	< 0.003	< 0.003	13.2	0.220
A19	R	15	< 0.003	< 0.003	2.70	16.4
A20	G	16	< 0.003	< 0.003	3.60	0.049
A3	I	26	< 0.003	< 0.003	2.20	3.30
A1	U	27	< 0.003	< 0.003	4.10	8.40

C - COMMERCIAL
R - RESIDENTIAL
E - EDUCATIONAL
M - MOTEL
G - GOVERNMENT
I - INDUSTRIAL
U - UTILITY

TABLE A-6

MEASURED ELECTRIC FIELD INTENSITIES IN AIR AT CASUALLY-OCCUPIED PLACES
NEAR THE CLAM LAKE ELF FACILITY

MEASURE- MENT LOCATION	LAND USE	DISTANCE TO ELF ANTENNAS (Miles)	76 Hz (VOLTS/METER)	60 Hz (VOLTS/METER)
A16	C	1	0.094	< 0.003
A15	C	1	0.057	0.003
A24	W	1	0.016	2.100
A12	C	2	0.025	0.017
A14	L	2	0.022	0.140
A13	C	2	0.014	0.003
A4	C	4	0.016	< 0.003
5	F	6	0.003	0.005
A22	C	6	< 0.003	< 0.003
3	F	7	0.006	0.005
6	M	7	0.006	< 0.003
22	F	7	0.004	< 0.003
24	F	7	< 0.003	0.024
23	F	8	0.012	0.013
21	F	8	< 0.003	< 0.003
4	F	9	0.003	0.018
1	P	13	0.030	0.160
2	P	13	0.005	0.009
25	M	13	0.004	0.024

C - Campground
F - Forest Area
L - Landfill
M - Meadow
P - Pipeline Right-of-Way
W - Wayside

A P P E N D I X B

Typical values of electromagnetic field intensities produced by commercial broadcast radio and television systems, power transmission and distribution systems, electric railways and various kinds of electrical appliances were included in Appendix A, Part C of the ELF Communications System Draft Environmental Impact Statement prepared by the Department of the Navy in February 1977. The information was then incorporated by reference in the Final Environmental Impact Statement filed with the Council on Environmental Quality by the Navy in December 1977. The National Academy of Sciences considered electromagnetic fields produced by commercial systems and appliances as well as the fields produced by ELF Communications Systems in its evaluation of biological implications of low-level, ELF electromagnetic fields reported in September 1977 as a supplement to the Navy's draft environmental impact statement (Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer; Committee on Biosphere Effects of Extremely Low Frequency Radiation, Assembly of Life Sciences, National Research Council, National Academy of Sciences). These documents may still be available in Reference Sections of numerous educational and public libraries in Wisconsin, Michigan and elsewhere. The information is summarized and other supplemental information is provided in this appendix as a convenience to readers lacking easy access to the original documents.

TABLE B-1

MAGNETIC FIELD INTENSITIES IN AIR AND EARTH

MEASUREMENT OR REFERENCE CONDITION	FREQUENCY	MAGNETIC FIELD INTENSITY (GAUSS)	
Earth's magnetic field	Essentially steady field of slowly varying intensity	0.5	approximately throughout U.S.
Measurements under high voltage transmission lines (intensity varies with line current)	60 Hz	0.01-0.1	
19 Measurements made in Wisconsin paper mill	60 Hz	0.003-0.06	
Measurements made in scientific laboratories	60 Hz	0.005-0.05	
8 Measurements made aboard submarines	60 Hz	0.002-0.04	USS Jack
48 Measurements made in three different hospitals	60 Hz	0.003-0.008	Patient areas and laboratories
Measurements at "user distances" from electrical appliances (values depend upon model and manufacturer)	60 Hz	10 - 25 5 - 10 1 - 5 0.1 - 1 0.001 - 0.01	Hair Dryer Electric Range TV Receiver Vacuum Cleaner Refrigerator
Measured (Wisconsin) or Planned (Michigan) under ELF transmitting antennas	76 Hz	0.06 0.03	(300 Amperes, Wisconsin) (150 Amperes, Michigan)

TABLE B-2

ELECTRIC FIELD INTENSITIES IN EARTH

MEASUREMENT OR REFERENCE CONDITIONS	FREQUENCY	ELECTRIC FIELD INTENSITY (VOLTS/METER)
9 Measurements under high voltage power transmission lines (values depend upon line currents)	60 Hz	0.01-0.6
171 Measurements near customers' electric service lines and circuit grounds in northwestern Wisconsin	60 Hz	0.01-0.5
16 Measurements near hospitals	60 Hz	0.01-0.06
202 Measurements over 1000 square miles in northern Wisconsin	60 Hz	0.004-0.04
Measured (Wisconsin) and planned (Michigan) under ELF transmitting antennas	76 Hz	0.14 0.07
		(300 Amperes, Wisconsin) (150 Amperes, Michigan)

TABLE B-3

ELECTRIC FIELD INTENSITIES IN AIR

MEASUREMENT OR REFERENCE CONDITION	FREQUENCY	ELECTRIC FIELD INTENSITY (VOLTS/METER)	
Typical Storm-Cloud Atmosphere	Non-alternating	2000	between Earth's surface and 3000 meter height; Cobb, 1967
Typical Cloud-Free Atmosphere	Non-alternating	17	between Earth's surface and 3000 meter height; Cobb, 1967
Measured near and under high voltage power transmission lines (values vary with line construction details)	60 Hz	7000	under 765KV Line
		5000	100 feet from 765KV Line
		5000	under 345KV Line
		500	100 feet from 345KV Line
Typical under 7200-volt commercial power distribution lines near consumers' homes	60 Hz	200	
Measured 12 inches from electric appliances (values depend upon manufacturer and model)	60 Hz	250	electric blanket
		90	phonograph
		60	refrigerator
		40	toaster
		15	clock radio
		4	electric range
Typical under ELF antennas	76 Hz	2	lamp
		200	near transmitter building
		0	near antenna grounds